Condensation Concerns

Introduction

Sudden changes in the weather can result in minor short-term condensation problems that concern some homeowners. Efforts to conserve energy, such as changing the heating system, improving airtightness or building a new energy-efficient home, have resulted in more significant condensation problems.

This publication should help to put concerns in perspective. The severity of condensation and its effect on your home depends on many factors. A few windows fogged up on cold days or an isolated spot of mould are not likely to be serious. Large ceiling stains or water running down windows and walls are serious problems and need immediate action.

This booklet discusses typical condensation problems, their causes and solutions.

Understanding Condensation

Interior surfaces of a home can be at different temperatures, depending on insulation, air leakage, exterior air temperature and exposure to sun and wind. The coldest surfaces are of greatest concern.

Usually the coolest interior surface temperature is on the window glass (Figure 1). Interior air coming in contact with it is cooled to the point where condensation occurs. The amount of condensation increases as the surface temperatures drop or as water vapour increases.

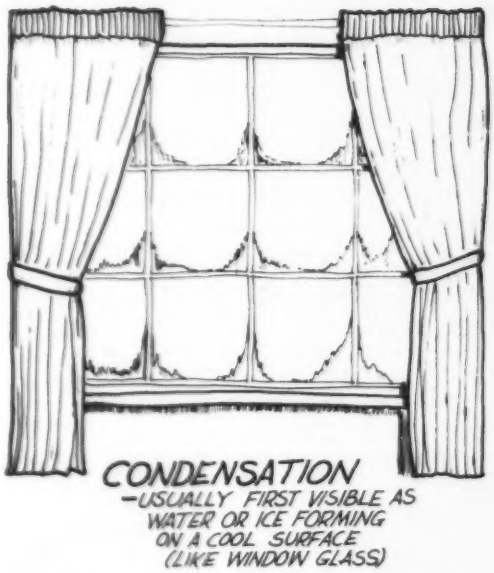

Figure 1

What is Condensation?

Condensation is the change of water vapour in the air to liquid water on a cold surface. It occurs because air holds only a limited amount of water vapour at any given temperature. The lower the temperature, the less water vapour the air can hold.

If the temperature of moist air is lowered by a cool surface (beyond its maximum water-vapour-holding capacity) water will form on that surface -- this water is condensation.

Surface Condensation

Surface condensation is a visible indication of a high moisture content in the air or a cold surface. It is a common problem in Alberta homes and usually requires only minor actions to prevent. It appears as condensation on windows, inner wall surfaces, toilet tanks and cold water pipes or around electrical outlets. Surface condensation is not necessarily serious but can become a problem if it persists for many days on many surfaces or to the point where it results in staining, mould growth or finish deterioration.

Table 1 lists outdoor temperatures and the indoor humidity levels at which condensation appears on inner glass surfaces -- usually the coolest surface in a room. The table shows that at cold exterior temperatures it is difficult to maintain the 40 to 50 per cent interior humidity level recommended by health professionals without some condensation on window surfaces.

Table 1

Window Condensation*

If the outside temperature is:	Then condensation will occur on the inner surface if the interior relative humidity rises above:	
^{0}C (^{o}F)	**Double Glazed Windows %**	**Triple Glazed Windows %**
-40 (-40)	25	36
-34 (-35)	28	39
-28 (-20)	33	44
-23 (-12)	38	48
-18 (0)	44	53
-12 (10)	50	63
-7 (20)	57	67
-1 (30)	63	72

* Room air temperature at 21^{o}C (70^{o}F)

Note: Covering the window with curtains can restrict air movement and result in a cooler glass surface which increases condensation.

Table 1 shows triple glazed windows (three layers of glass -- Figure 2) will allow higher interior relative humidity levels without condensation than double glazed units. The extra glass and trapped air between helps keep the inner surface warmer. New energy efficient units, such as low-e (emissivity) with argon, should perform as well as or better than triple glazed units. Any increase in RSI (R) value of the window allows it to perform better than a unit of lower RSI (R) value. RSI value (R value) refers to the resistance to heat flow - the higher the better.

Interior surface condensation can occur on any cool surface -- cold water pipes, toilet tanks, poorly insulated walls or floors, metal hinges or locks on exterior doors -- not just on window surfaces. A high relative humidity with cold surface temperatures creates the most problem. This type of condensation can occur no matter how well built a home is.

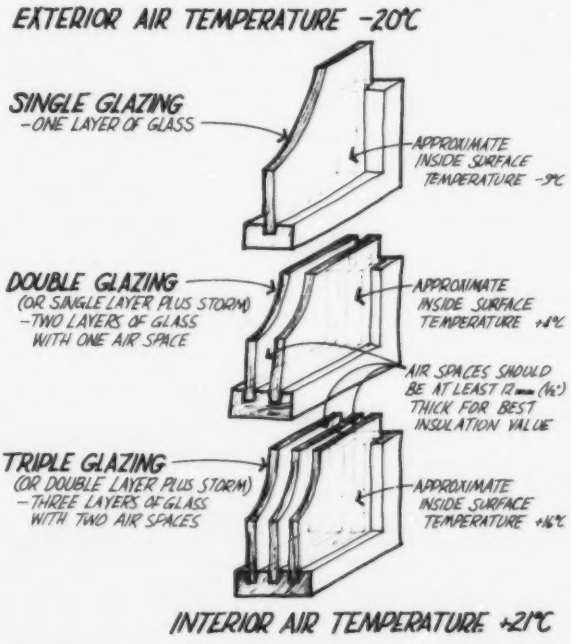
EXTERIOR AIR TEMPERATURE -20°C
SINGLE GLAZING
-ONE LAYER OF GLASS
APPROXIMATE INSIDE SURFACE TEMPERATURE -9°C
DOUBLE GLAZING
(OR SINGLE LAYER PLUS STORM)
-TWO LAYERS OF GLASS WITH ONE AIR SPACE
APPROXIMATE INSIDE SURFACE TEMPERATURE +1°C
AIR SPACES SHOULD BE AT LEAST 12 mm (½") THICK FOR BEST INSULATION VALUE
TRIPLE GLAZING
(OR DOUBLE LAYER PLUS STORM)
-THREE LAYERS OF GLASS WITH TWO AIR SPACES
APPROXIMATE INSIDE SURFACE TEMPERATURE +16°C
INTERIOR AIR TEMPERATURE +21°C

Figure 2

Concealed Condensation

Concealed condensation usually occurs when warm moist air goes out through cracks, gaps or holes in the building shell (walls, floors or ceilings). It may also result when water vapour diffuses through building materials. Diffusion, the molecular movement of water vapour through solid materials, is caused by differences in vapour pressure. Diffusion of water vapour accounts for a small portion of moisture movement through the walls of homes. The greatest problems with concealed condensation result from the leakage of warm moist air through the building shell.

If warm moist air leaks out through a gap in the building shell during cold weather, at some point in the passage air will cool to the point where it reaches 100 per cent relative humidity Condensation occurs on the closest non-porous surface -- often the inside face of exterior sheathing. (Figure 3). If the outside temperature is quite low, water vapour may deposit directly as ice or frost.

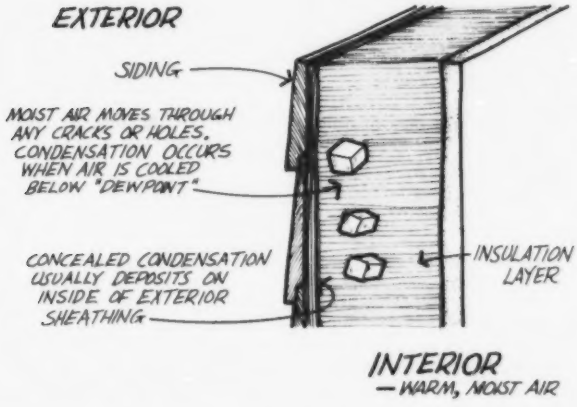
EXTERIOR
SIDING
MOIST AIR MOVES THROUGH ANY CRACKS OR HOLES. CONDENSATION OCCURS WHEN AIR IS COOLED BELOW "DEWPOINT"
CONCEALED CONDENSATION USUALLY DEPOSITS ON INSIDE OF EXTERIOR SHEATHING
INSULATION LAYER
INTERIOR
— WARM, MOIST AIR

Figure 3

If the amount is small, it may change right back into water vapour and be carried away by natural air movement with little damage to the structure. But large deposits of ice will melt and can soak insulation materials, destroy interior or exterior finishes, or lead to structural deterioration.

Fortunately, concealed condensation is not generally a major problem in our climate. Air leakage in the normal home involves warm air moving out through vents, ducts and chimneys. The cold air drawn in to replace it carries little total moisture -- the initial relative humidity may be quite high, but as the air warms to room temperature the relative humidity may be reduced to less than 10 per cent. The resulting dry indoor environment, often requiring humidification, is usually a sign that a great deal of outside air is leaking in. This causes drafts, reduces comfort and increases heating costs.

Even in our climate concealed condensation can result when vapour diffusion is reduced on the outside of a wall when re-siding. Moisture that normally moved through the wall is now trapped. Resulting condensation could cause deterioration of the insulation or the structure. When re-siding you should seal all leakage areas -- such as behind the baseboard and around electrical outlets -- from the inside to reduce moisture movement into the wall.

Causes of Condensation and Solutions

Identifying the Problem

Every homeowner should know how to recognize condensation problems, how to evaluate their seriousness and how to solve them. A sudden increase in humidity may indicate a basement leak, a broken water pipe or a faulty chimney -- all harmful problems to be remedied immediately. Common locations of condensation and moisture buildup, possible causes and suggested solutions are outlined in Table 2. It shows that most problems are a result of high humidity levels and such causes as air leakage, a cold surface or sudden temperature drop.

Table 2
Condensation Problems, Causes and Solutions

Area	Indication	Possible Causes	Suggested Solutions
Windows	Condensation on most inside surfaces of inner pane	• Abnormally high humidity	• Control humidity sources (Table 5) • Add layer of glass or plastic on inside (Table 1) to increase interior surface temperature (Figure 2)
		• Lower thermostat setting at night	• Condensation should disappear as house warms up (adjust thermostat setback slightly higher if condensation is severe)
		• Sudden change to colder weather	• Ventilate home to lower humidity level; control sources of moisture (humidifier, showers, etc.)
		• Poor air circulation	• Improve circulation by opening drapes; moving furniture or objects blocking registers; running furnace fan continuously
	Condensation on upper storey windows only	• Cool air leaking into lower level, warm air leaking out upper level	• Improve caulking, weatherstripping to reduce cold air infiltration (see *Caulking and Weatherstripping);* ensure there are adequate fresh and combustion air supplies (Figure 5)
	Condensation on windows on one side of house only	• Cold air in on windward side, warm air out on downwind side	• Improve caulking and weatherstripping to reduce cold air infiltration (see *Caulking and Weatherstripping)*
	Condensation on north windows only	• Inner surfaces cooler than south windows in daylight	• Open drapes and improve circulation; add layer of glazing on inside
	Condensation on windows, 1-2 rooms	• Room(s) cooler than rest of house	• Improve circulation by opening drapes; leaving room door(s) open; run furnace fan continuously
		• High humidity rooms: laundry, room w/ humidifer	• Exhaust dryer to outside; shut off humidifier
	Condensation between layers of glazing	• Air leakage from inside into space between glazing	• Seal inner pane between glass layers with caulking or replace weatherstripping between sliding units (see *Caulking and Weatherstripping)*
		• Outer storm window sealed	• Seal inner unit; allow outer unit to breathe to exterior
		• Broken seal	• Replace window with good new sealed unit capable of withstanding relative humidity levels
	Condensation on window frame	• Air leakage: rough opening space, poor weatherstripping	• Seal between frame and rough opening space; improve caulking and weatherstripping (see *Caulking and Weatherstripping)*
		• Air leakage: frame, sash, meeting rails	• Install sealed interior plastic or Plexiglas storm or shutter
		• Poor quality metal or plastic frames	• Replace with good quality wood or units with a thermal break
	Condensation on doors	• Uninsulated door	• Replace with insulated door; add storm door
Doors	Condensation on door frame/threshold	• Air leakage around door	• Replace, adjust weatherstripping, threshold; add storm door (see *Caulking and Weatherstripping)*
	Condensation on lock, knob, hinges	• Air infiltration due to negative pressure inside	• Replace weatherstripping; add fresh air duct to heating system add storm door

Area	Indication	Possible Causes	Suggested Solutions
Walls	Condensation on closet walls	• Poor air circulation around clothes	• Improve air circulation: open doors; add louvres, grilles; undercut doors; leave space by outside wall
	Condensation and staining below window	• Melted window condensation	• Improve window as above
		• Window in humid area	• Eliminate window unit, insulate opening
		• Insulation missing	• Add insulation to wall cavity
	Condensation on many walls	• Abnormally high humidity	• Control humidity sources (Table 5)
		• Poor air circulation	• Run furnace fan continuously
		• Missing insulation	• Add insulation to wall cavities
	Condensation in corners	• Incoming air	• Caulk siding corners, window brick moulds, siding - parging joint, etc. to exterior (see *Caulking and Weatherstripping*)
		• Thermal bridging, missing insulation	• Add insulation in wall or on outside
		• Poor air circulation	• Aid circulation: move furniture/objects blocking registers; run furnace fan continuously
	Mould on Wall	• Abnormally high humidity	• Control humidity sources (Table 5)
		• Poor ventilation	• Use fans; add mechanical ventilation (Figure 6)
		• Poor air circulation	• Aid circulation: move furniture/objects blocking registers; run furnace fan continuously
	Frost on basement walls	• Abnormally high humidity levels	• Control humidity sources (Table 5)
		• Air leakage at sill plate, uninsulated walls	• Seal and insulate basement walls (see *Basement Insulation and Caulking and Weatherstripping*)
	Condensation around electrical outlets	• Incoming cold air	• Seal under plates (see *Caulking and Weatherstripping*)
	Water on basement floor or walls	• External sources like runoff, rain or ground water	• Seal wall; install weeping tile; direct gutter drains away from wall; maintain ground slope away from wall; check that existing weeping tiles are open
		• Abnormally high moisture level	• Control sources of moisture (Table 5)
	Stains on ceiling	• Frost buildup melting in attic when weather warms	• Add vents to overcome inadequate attic ventilation; seal air leaks into attic space from below (see *Attic Insulation*)
		• Leaking roof	• Repair roof leak
	Frost on exposed nails in attic	• Small amount of warm air leaking into attic space	• Occurs normally during cold weather in most homes (check for adequate ventilation (see *Attic Insulation*)
Ceiling/ Attic	Large isolated frost deposit in attic	• Indicates large volume of warm and moist air leaking into attic space	• Identify source; caulk or seal leak at ceiling level (large amounts usually occur around stacks or from poorly sealed exhaust ducts - make sure all exhausts vent to exterior, not into attic space)
		• Inadequate attic space ventilation	• Add attic vents (*see Attic Insulation*)

(Continued on Page 7)

Moisture Sources and Causes

Normal Home Operation

In an average home there are many sources and causes of humidity -- some evaporating periodically, some constantly, others adding moisture directly to the air. Table 3 identifies typical sources of moisture.

Table 3

Moisture Sources

Type	Source	Litres (Gallons) Added Per Week to Air
Continuous	Occupants (4)	30-40 (7-9)
	Showers (8/wk.)	18-29 (3-5)
	Drying clothes	12 (2.6)
	Cooking (steam)	9 (2)
	Gas cookstove	9 (2)
	Refrigerator (Frost free)	9 (2)
	Dishwashing (sink)	3 (0.7)
	Large house plant (over 1 metre)	3 (0.7)
	Bathing (8/wk.)	3 (0.7)
	Laundry	2 (0.4)
Seasonal	Summer moisture (trapped when windows closed in fall - may last 3 or 4 weeks)	40 (9)
	Damp basement or crawlspace	14 (3)
	Unvented kerosene heaters (depends on use)	5 (1.1)

Most Alberta homes quickly eliminate the extra moisture in their atmosphere and condensation is not a problem. Many have such a low relative humidity in winter that humidifiers are used to add water vapour to the air. Figure 4 (top) shows that air leakage and the effect of the chimney continually exhausting warm air results in outside air being drawn in. Regardless of its initial relative humidity, when that cold air is heated to room temperature it is quite dry and readily absorbs the normal moisture production of the home.

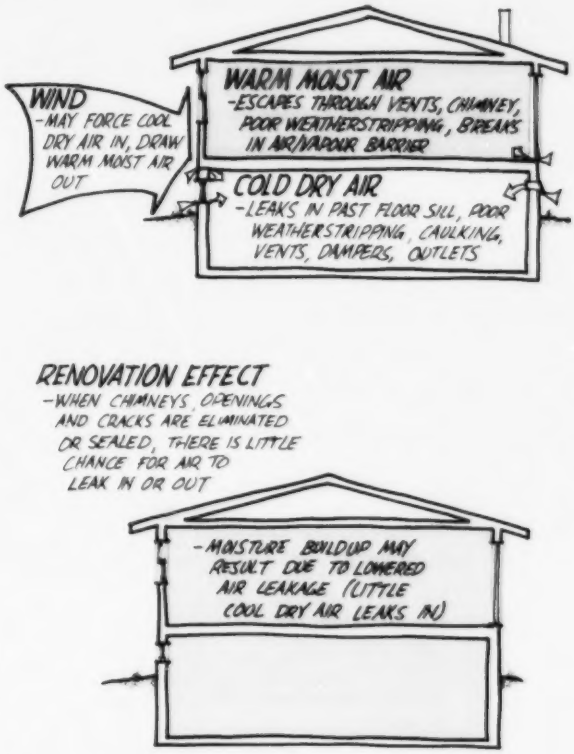
WIND
-MAY FORCE COOL DRY AIR IN, DRAW WARM MOIST AIR OUT
WARM MOIST AIR
-ESCAPES THROUGH VENTS, CHIMNEY, POOR WEATHERSTRIPPING, BREAKS IN AIR/VAPOUR BARRIER
COLD DRY AIR
-LEAKS IN PAST FLOOR SILL, POOR WEATHERSTRIPPING, CAULKING, VENTS, DAMPERS, OUTLETS
RENOVATION EFFECT
-WHEN CHIMNEYS, OPENINGS AND CRACKS ARE ELIMINATED OR SEALED, THERE IS LITTLE CHANCE FOR AIR TO LEAK IN OR OUT
-MOISTURE BUILDUP MAY RESULT DUE TO LOWERED AIR LEAKAGE (LITTLE COOL DRY AIR LEAKS IN)

Figure 4

There may be situations when water vapour production is greater than loss. Increased caulking and weatherstripping to reduce air leakage, the installation of a chimneyless furnace, a serious water leak or a blocked chimney are but a few things which can change the moisture balance. Cold air being continually drawn in (a negative pressure) can result in warm air being forced out (a positive pressure) -- shown in Figure 4 (bottom).

Changes to Normal Home Operation

Excessive humidity and surface condensation become problems when previous routes for moisture escape are closed or when more moisture is produced than can escape. The average home needs about 55 litres per second (110 cubic feet per minute) of ventilation to control humidity and maintain air quality.

Higher insulation levels and lower air leakage rates, the result of extensive retrofitting or the building of a new energy-efficient house, can cause higher interior humidity levels. The humidity can be controlled using a ventilation system (Figures 5, 6 and 7).

Table 4 summarizes some unusual causes or sources of high humidity.

Table 4

Unusual Causes and Sources of High Humidity

Cause / Source of Moisture	Comments
Faulty or plugged chimney serving any fuel-fired appliance (furnace, hot water heater, etc.)	Water vapour is a major byproduct of combustion so unusually high moisture levels can be an indication of a plugged or leaking chimney vent and MUST BE CORRECTED IMMEDIATELY (have heating contractor or utility company test system)
New home or large addition	As much as 36 litres (8 gallons) of moisture a week are released from building and finishing materials during the first 18 months
New, energy-efficient home	Low air leakage rate and moisture from building materials means ventilation (Figures 5 and 6) must be used to prevent the buildup of moisture from day-to-day activities
Extensive renovation for energy efficiency	Plugging air leaks means moisture that formerly leaked out (Figure 4) must now be ventilated
Installation of a high-efficiency (chimneyless) furnace	Eliminating the chimney stops a major source of air leakage. Additional ventilation may be needed
Flooded basement	A major water source such as a broken water pipe, spring run-off or a high water table can bring up to 900 litres (200 gallons) of moisture into the home each week -- proper ground slope, weeping tile and gutters directed away from basement walls are essential for controlling water movement
Minor leaks and water sources	Leaking roofs, water pipe leaks, badly dripping taps, carpet steam cleaning, mopping floors or storage of green wood can introduce a lot of moisture -- recognize and control the source
Other	Operating an indoor hot tub or pool, maintaining a tropical atmosphere for plants or throwing a large party can overload the home with moisture

Table 2 continued

Area	Indication	Possible Causes	Suggested Solutions
Other	Condensation on cold surfaces such as pipes, toilet tank, etc.	• Abnormally high humidity level • Cold water supply	• Control humidity sources (Table 5) • Insulate pipes or toilet tank
	Exterior paint peeling	• Lack of air/vapour barrier • Rain penetration behind siding	• Add air/vapour barrier to interior or paint with vapour barrier paint on interior surfaces; seal around electrical outlets • Identify and caulk any leaks or gaps on exterior; repair flashings
	Structural damage to studs, joists or rafters	• Bacterial action due to warm, moist and dark environment	• Identify cause of leakage (external or concealed condensation); replace damaged members' seal wall, floor or ceiling assembly to prevent recurrence

Controlling Moisture

Table 5 outlines steps than can be taken to lower home humidity levels. The initial steps are simple and may provide easy solutions. Working further through the chart leads to more complex and detailed solutions -- but in cases of high humidity and low air leakage, these may be required. **Always try the simple steps first.**

If they don't work, use the more complex solutions.

Use the information to help identify the sources of moisture so specific ones can be controlled. Some information in Table 5 will require a fair amount of work and expertise to carry out. Information following the table provides details on techniques suggested.

Table 5

Controlling Humidity

Action Required	Comments
Personal actions	• Cover cooking pots (eliminates steam, conserves energy) • Do not hang wet clothes inside to dry • Take shorter showers
Turn humidifiers down (or off)	• May require shutting off water supply to furnace humidifer • Use individual room humidifiers sparingly
Check that clothes dryer is vented to exterior	• Electric and gas dryers MUST BE VENTED TO EXTERIOR (electric dryer may have been vented indoors as a heat-saving measure)
Operate venting fans	• Use individually to control humidity from showers, cooking, etc. (run a few minutes after the activity to ensure moisture is removed)
Operate furnace fan continuously	• Set switch for summer operation (fan runs constantly) • Use two-speed fan (runs continually at low speed, switches to high speed for heating cycle) • Improved circulation will help reduce localized condensation
Isolate moisture - producing areas	• Close windows and doors to greenhouses, indoor pools and hot tub spaces • Do not draw air into the heating system from humid areas • Add separate exhaust venting system
Cover exposed earth in basements/crawlspace	• Must have a ground cover like heavy polyethylene or roll roofing overlapped by 100 mm (four inches) and weighed down or protected by sand layer (ventilate space in summer according to Alberta Building Code)
Increase outside air supply to heating system	• Fresh air duct with variable damper allows a controlled amount of dry outside air into the home (Figure 5)
Add mechanical venting	• Install fans in moisture-producing areas: bathrooms, laundry areas, kitchen • Install a central fan controlled by a humidistat (operates only when the humidity above preset level - Figure 6)
Install air-to-air heat exchanger into venting system	• Can recapture part of the heat from the outgoing air (Figure 7) • Expensive item (costs and benefits must be considered)

Note: The installation of a dehumidifier is not a solution to overall home humidity problems because it is only capable of lowering the relative humidity to 50 or 60 per cent and is not suitable for colder basements.

Increasing the Fresh Air supply

One method that may be required to control humidity buildup is to install a controlled source of fresh air. An insulated duct is installed from outside to the return air plenum of the forced-air heating system (Figure 5). Although required by the building code in new homes, a fresh air supply source is often lacking in older homes. Installing a duct introduces a new source of dry outside air in homes renovated to cut down air leakage heat loss. For correct operation, the damper is adjusted so that a small amount of condensation shows on the inside of window glass. It is then opened or closed as necessary to maintain the slight condensation as the outside temperature varies.

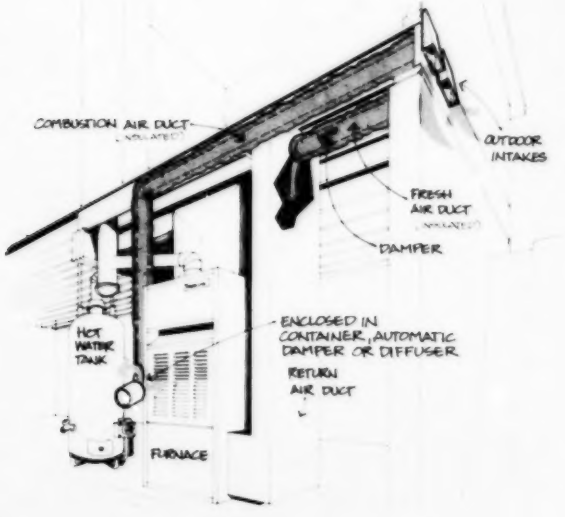

Figure 5

This duct provides fresh air for humidity control while a separate duct should be installed to supply combustion air for fuel-burning appliances like the furnace, hot water heater or boiler (Figure 5). It should not have a manual damper. Approved automatic dampers are available. They automatically close and open according to the requirements of the heating unit.

Adding Mechanical Ventilation

Older homes often do not have exhaust fans in moisture-producing areas like bathrooms, laundry room or kitchen. If a fan is required to control humidity, it is best to install it as shown in Figure 6 -- on an interior wall, venting down the wall cavity and out through the joist space. This eliminates potential problems in the attic. Make sure exhaust fans are powerful enough to move the air the distances required.

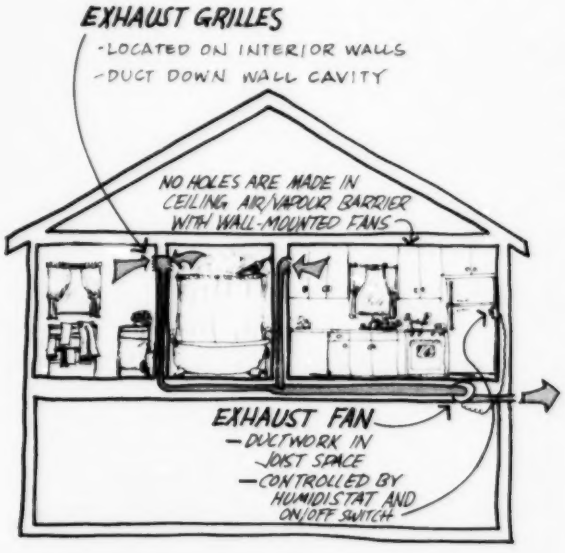
EXHAUST GRILLES
-LOCATED ON INTERIOR WALLS
-DUCT DOWN WALL CAVITY
NO HOLES ARE MADE IN CEILING AIR/VAPOUR BARRIER WITH WALL-MOUNTED FANS
EXHAUST FAN
—DUCTWORK IN JOIST SPACE
—CONTROLLED BY HUMIDISTAT AND ON/OFF SWITCH

Figure 6

If vents must be installed through the attic and roof or soffit, be sure they have automatically closing dampers. They must be sealed and insulated so that warm, moist air cannot leak into the attic space (see *Attic Insulation*).

If two or three exhaust locations are required, they can be joined and operated with a single, large variable-speed fan (Figure 6). Controlling the single exhaust fan with a dehumidistat allows the homeowner to set the desired humidity level and allow the fan to operate as needed at high speed when someone is showering or many people are in the home, at a slower speed during normal activities or shut off at night when little moisture is being produced. The desired humidity level will vary (high during warm weather, lower during cold weather) to keep window condensation at a minimum.

Operate the exhaust system at a minimal rate because it is heated air that is being blown out. The exhausted air must be replaced. If the house is airtight then air leakage will not provide enough make-up air. Replacement air can then be brought in through a fresh air vent as shown in Figure 5.

The ease of installation will depend on the accessibility to walls and the basement ceiling. The benefits in terms of efficiency and controlled ventilation, however, far outweigh those of standard ceiling fans units.

Incorporating a Heat Recovery Ventilator

As mentioned, operating exhaust systems can control the buildup of excessive humidity but remember the exhaust is also removing heated air -- air that you have paid to heat! If little air needs to be exhausted to control humidity, nothing can be done to recapture the heat. However, if large volumes of air are continually being exhausted, then a heat recovery ventilator can be installed to recapture a portion of the heat from the outgoing air.

Heat recovery ventilators are devices in which warm air is exhausted past cold incoming air. The two air streams are separated by a thin membrane which allows heat, but not odours, to be transferred (Figure 7). Although expensive, these devices can recapture part of the heat from exhaust air. They must be installed into a ventilation system from a centralized exhaust point (Figure 6). Heat exchangers are generally considered economically justifiable only in airtight, energy-efficient houses.

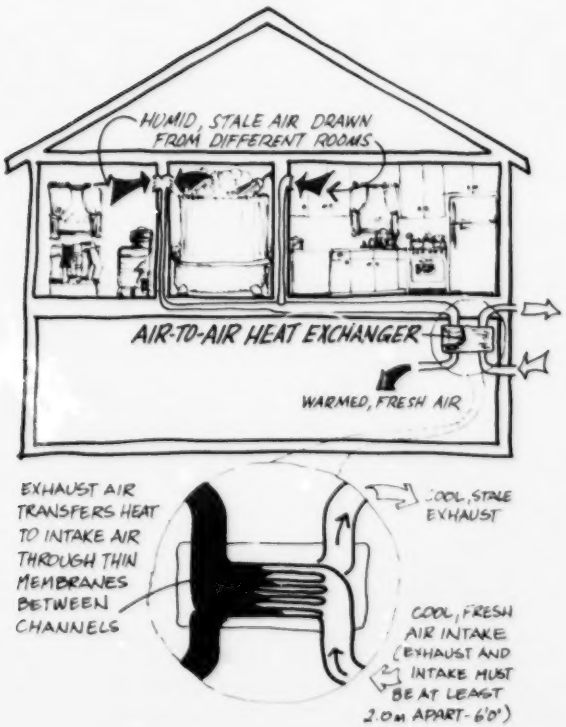
HUMID, STALE AIR DRAWN FROM DIFFERENT ROOMS
AIR-TO-AIR HEAT EXCHANGER
WARMED, FRESH AIR
EXHAUST AIR TRANSFERS HEAT TO INTAKE AIR THROUGH THIN MEMBRANES BETWEEN CHANNELS
COOL, STALE EXHAUST
COOL, FRESH AIR INTAKE (EXHAUST AND INTAKE MUST BE AT LEAST 2.0m APART - 6'0")

Figure 7

Summary

If there are signs the humidity level in your home is too high, try the following steps:

- Note the type of problem
  - a light fog on windows
  - dampness or frost on walls
  - stains on the ceiling
- Establish whether the problem is isolated or widespread
  - just a few windows fogged or a small stain on the ceiling
  - many windows or walls with condensation
  - only one or two areas of the home affected
- Determine the problem (use Table 2)
  - is the humidity level too high?
  - has there been a change to colder weather?
  - is there a water leak or other new source of moisture?
  - is your home new or has a large addition been constructed?
  - have there been any equipment changes?
  - has the chimney been checked recently for leaks or blockages?
  - have you taken measures to stop air leakage?
- Take action to rectify the situation
  - control the sources of humidity first
  - if condensation is isolated, remedy the problem area (air leak, water leak, missing insulation, etc.)
  - if condensation is widespread, add ventilation to lower the humidity level

By using the tables, diagrams and other information here you should be able to understand relative humidity and to control condensation problems.

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Condensation Concerns

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